Centrifugal Force Measurement

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المرحلة الثالثة

Centrifugal force measurement

Introduction

The centrifugal force a apparatus is designed to enable the students to determine the magnitude of the centrifugal force due to a mass revolving on an arm. Each of the parameters mass , radius of the arm and the angular velocity may be varied and the effect of each one of these variations on the value of the centrifugal force can be observed .

Apparatus

A schematic diagram of the centrifugal force apparatus is shown in Fig. (1). The horizontal rod AB is rotated about the vertical axis Y by a variable speed motor. The arm CD and EF are fixed to the rod AB by locking bolts but their distance (r) from the axis of rotation can be varied. Bell-cranks are pivoted at the point D and E. Each Bell-cranks carries two masses and as shown in the figure.

These masses can also be varied. At a low speed of the rod, the bell-cranks rest on the supports G and H. when the rotational speed of the rod is gradually increased, the bell-cranks float from the supports G and H and rest on the supports I and J.

Objects

1. to study the relation between different parameters.
2. to determine the angular velocity experimentally and then compare it with the measured value under the same conditions.

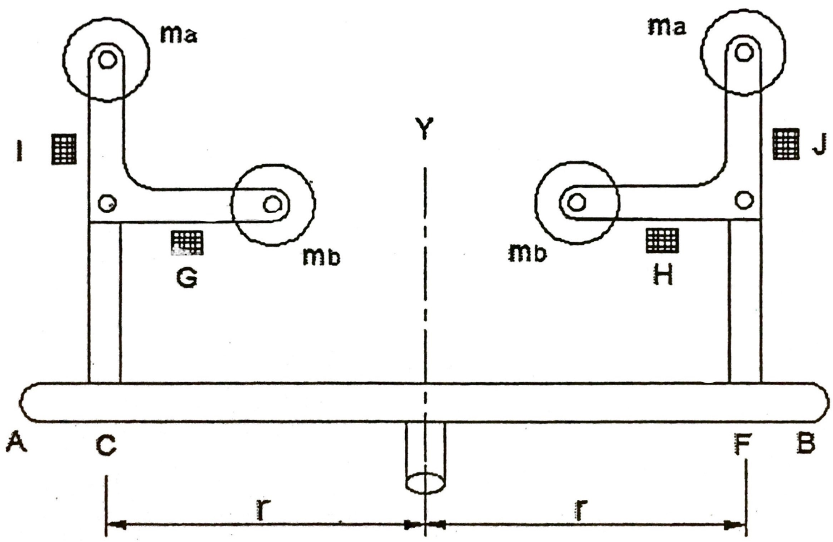


Fig. 1

Procedure

1. Connect the motor of the apparatus to a single phase AC supply through the control unit.
2. Turn, clockwise, the regulator of the control unit gradually to increase the speed of the motor.
3. Start increasing the motor speed unit you hear a click at the upper supports (I & J). record the motor speed at this point. Repeat the above procedure decreasing the motor speed until again you hear a sound of click at the lower support (G & H), then record the motor speed. Now, take the average reading of the upper two speeds.
4. Bring the digital on the control unit to zero by pressing knob near it.
5. Press the counter knob for recoding revolution and simultaneously start a stopwatch. Also, count the number of the green flashes, which indicates the number of revolutions.
6. After about 30 seconds press the counter knob again and simultaneously stop the watch.
7. find the angular speed (ω) of the rod AB from the following formula:

$$\omega = \frac{\textit{Number of revolution}}{\textit{stopwatch reading}} * 2\pi \qquad (rad/\text{sec}) \text{ .... } 1$$

8. stop the motor and change either the masses (m_a & mb) or the distance (r) of the arm as required.
9. Repeat the procedure above for the other readings.

Theory

When the bell-cranks are floating that is, not touching either of the supports, the force acting on a bell-cranks are shown in Fig.(2)
Taking moment about D , we get

$$a m_a r\omega^2 - m_b g b = 0$$

Or

$$\omega^2 = \left(\frac{m_b}{m_a}\right)\left(\frac{b}{a}\right)\left(\frac{g}{r}\right) \text{ .... } 2$$

For this apparatus b/a = 12/7

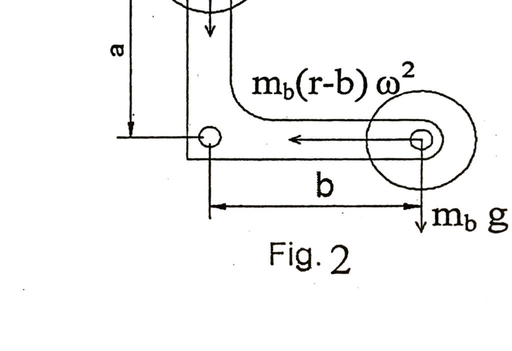


Fig. 2

Therefore,

► **If** mass (m_a) and the arm distance (r) are kept constant

$\omega^2 \ \alpha \ m_b$

► **If** mass (m_b) and the arm distance (r) are kept constant

$\omega^2 \alpha \ 1/m_a$

► **If** masses (m_a & m_b) are kept constant

$a^2 \ \alpha \ 1/r$

► **If** masses (m_a & m_b) and the distance (r) are known, then (ω) may be determined from above.

Results

► keep mass (m_a)and the arm distance (r) are kept constant and vary mass m_b to take at least 4 reading. Plot (co^2) against (m_b) to verify that

$\omega^2 \alpha \ m_b$

► keep mass (m_b) and the arm distance (r) are kept constant and vary mass m_a to take at least 4 reading. Plot (ω^2) against (l/m_a) to. verify that

$\omega^2 \alpha \ 1/ m_a$

►- keep mass (m_a)and (m_b) constant and vary the arm distance (r) to take at least 4 reading Plot (co^2) against (1 /**r**) to verify that

$\omega^2 \alpha \ 1/ r$

► take the reading with known masses and known arms distance (r) find (ω)from both Eq. (1) & (2) and compare.

Discussion

Discussion the source of error in the experiment.

Sample of Calculations

For one reading:
m_a = 450 g
m_b = 900 g
r = 11.5 cm
N = 78 rev/30 sec

$\omega_{exp} = 2\pi \times \frac{No.of\ revolutions}{time\ (30\ sec)} = 2\pi \times \frac{78}{30} = 16.336$ (rad/s)

$\omega_{exp} = 16.336$ (rad/s)

$\omega^2_{th} = \frac{mb}{ma} \times \frac{b}{a} \times \frac{g}{r} = \frac{900}{450} \times \frac{12}{7} \times \frac{9.81}{0.115} = 292.47$

$\omega_{th} = 17.101$ (rad/s)

$F_{exp} = m_a \times r \times \omega^2_{exp} = \frac{450}{1000} \times \frac{11.5}{100} \times (16.336)^2 = 13.81$ N

$F_{th} = m_a \times r \times \omega^2_{th} = \frac{450}{1000} \times \frac{11.5}{100} \times (17.101)^2 = 15.135$ N

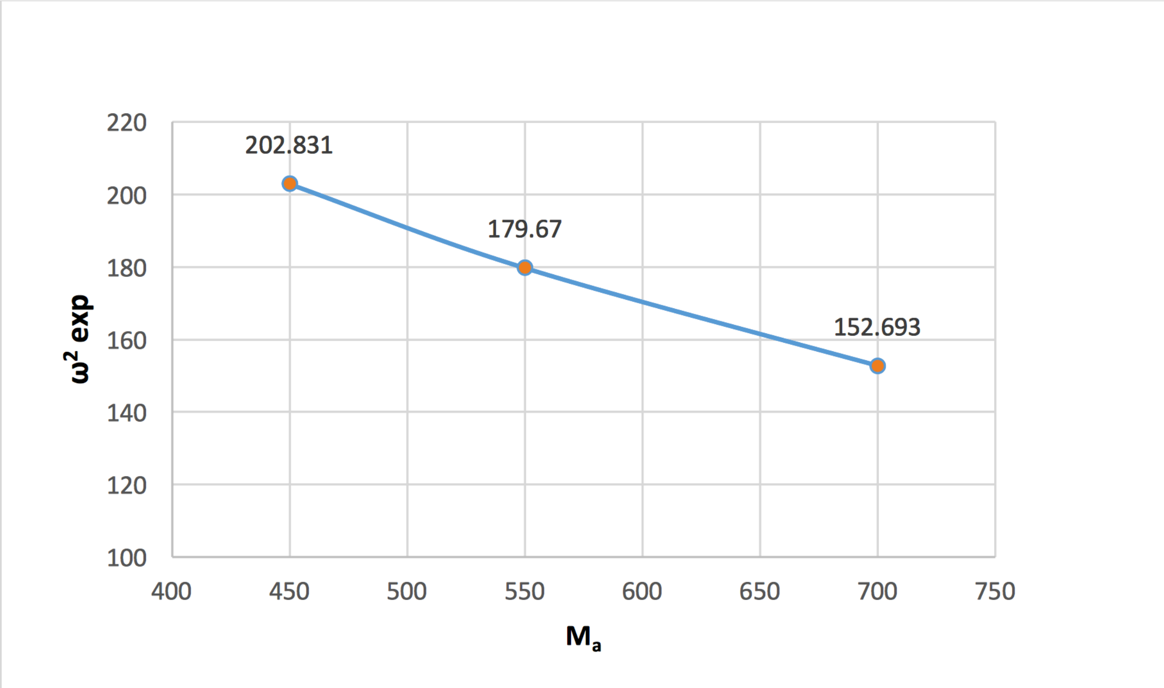
Table of Results

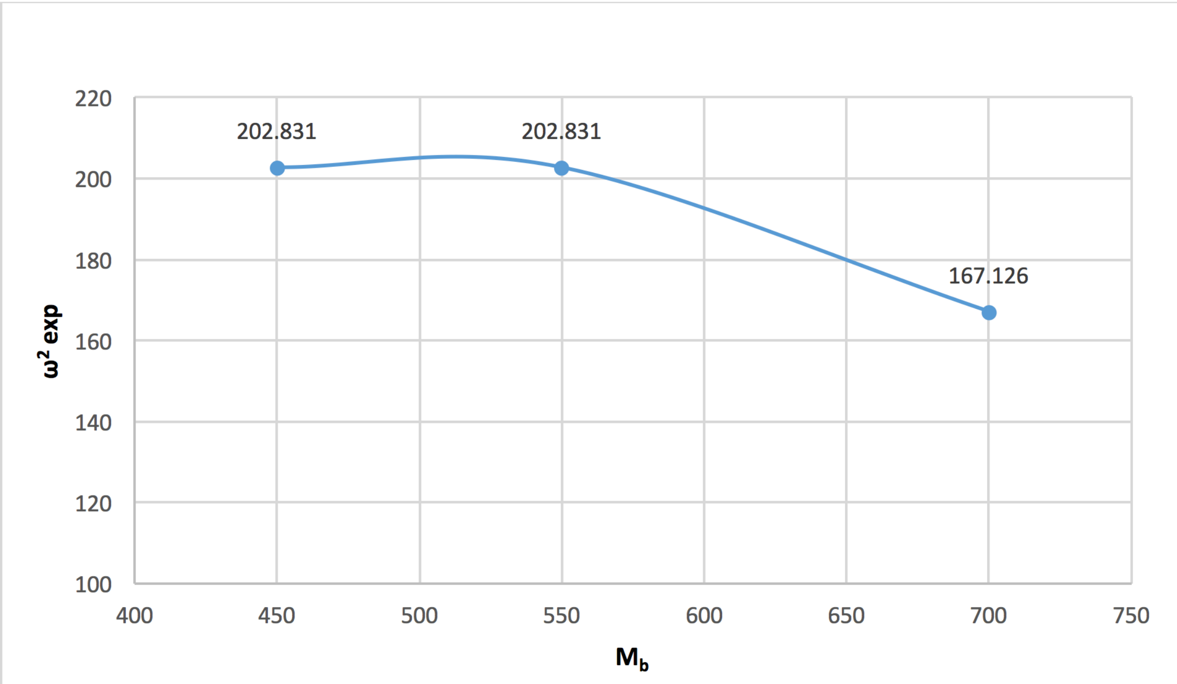
M_a (g)	M_b (g)	r (cm)	N	ω^2_{exp} rad/s	ω^2_{th} rad/s	F_{exp} (N)	F_{th} (N)
450	700	11.5	68	202.831	227.478	10.496	11.771
450	800	11.5	74	240.204	259.975	12.430	13.453
450	900	11.5	78	266.874	292.472	13.810	15.135

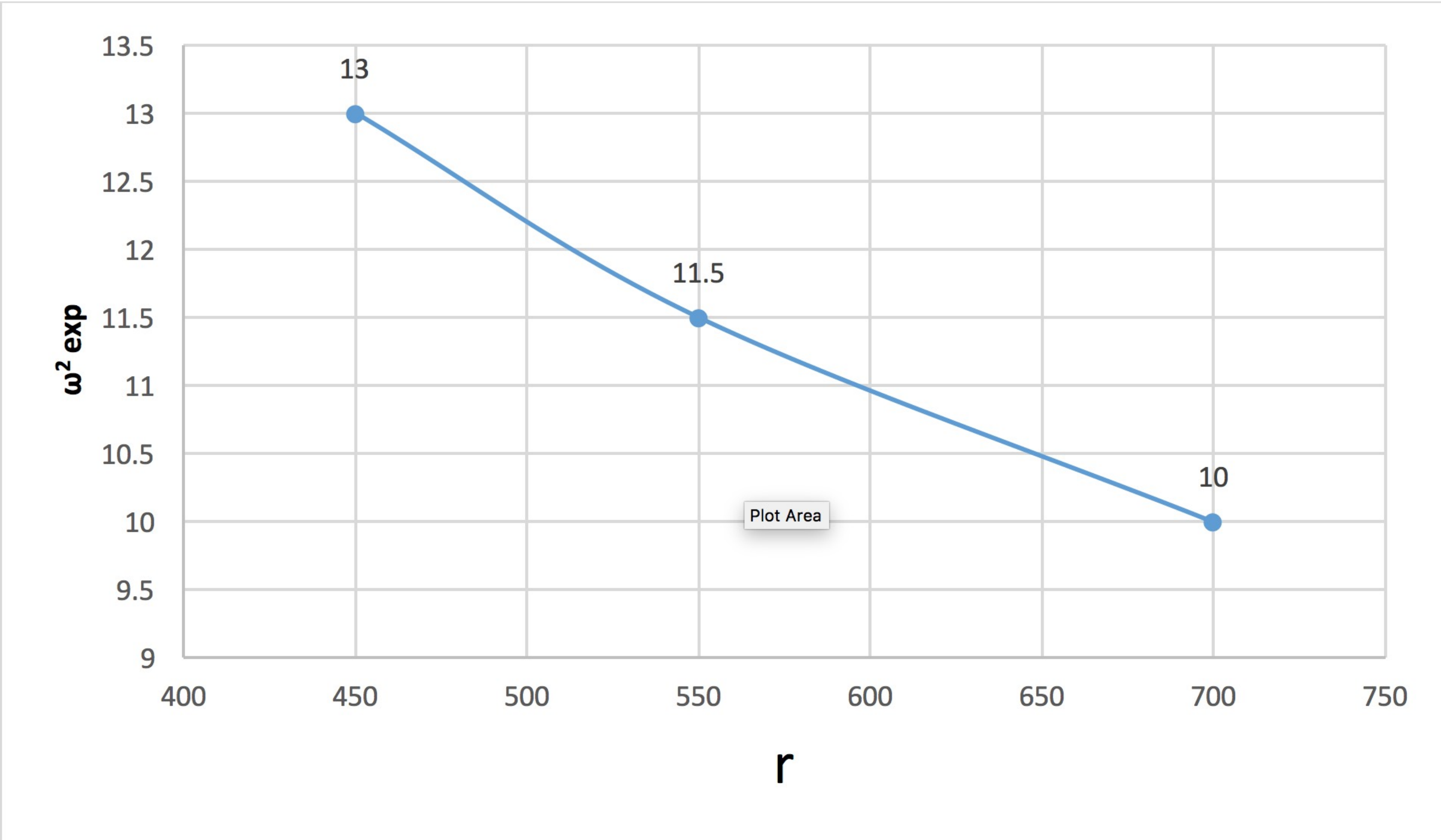
M_a (g)	M_b (g)	r (cm)	N	ω^2_{exp} rad/s	ω^2_{th} rad/s	F_{exp} (N)	F_{th} (N)
450	800	11.5	74	240.204	259.975	12.496	13.453
550	800	11.5	68	202.831	212.706	12.829	13.453
700	800	11.5	59	152.693	167.128	12.291	13.453

M_a (g)	M_b (g)	r (cm)	N	ω^2_{exp} rad/s	ω^2_{th} rad/s	F_{exp} (N)	F_{th} (N)
550	800	11.5	68	202.831	212.706	12.829	13.453
550	800	13	64	179.67	188.163	12.810	13.453
550	800	14.5	60	157.913	168.698	12.593	13.453

Graphs


202.831
179.67
152.693
220
200
180
160
140
120
100
400
450
500
550
600
650
700
750
ω^2 exp
M_a


202.831
202.831
167.126
220
200
180
160
140
120
100
400
450
500
550
600
650
700
750
ω^2 exp
M_b


13.5
13
12.5
12
11.5
11
10.5
10
9.5
9
13
11.5
10
Plot Area
ω2 exp
400
450
500
550
600
650
700
750
r

Discussion & Application

Centrifugal force is ubiquitous in our daily lives. We experience it when we round a corner in a car or when an airplane banks into a turn. We see it in the spin cycle of a washing machine or when children ride on a merry-go-round. One day it may even provide artificial gravity for space ships and space stations.

From the experiment, it was realized that the Centrifugal force depends on many factors such as the weight, the distance between the body and the center and the rotation speed or revolutions per minute, the Centrifugal force will be greater if one or all of these factors was bigger